Testing and Utilization of Next-Generation Migrating Corrosion Inhibitors

Jessi Meyer, *Cortec Corp., St. Paul, Minnesota*

Migrating corrosion inhibitors have been utilized in the construction industry over the past 25 years. Lab and field testing have confirmed their benefit in extending the durability of concrete exposed to corrosive environments. This article describes the tests done and gives examples of their use.

The latest generation of migrating corrosion inhibitors (MCIs) contains a blend of amine-based inhibitors, but is based mostly on amine carboxylates. These organic compounds are derived from sugar beets, a renewable source, and are called "mixed" corrosion inhibitors, meaning they affect both anodic and cathodic portions of a corrosion cell. Their use adds to the durability of structures by reducing corrosion. Many of these MCIs have NSF/ANSI Standard 61[1] certification, meaning they are safe for use in structures holding potable water.

MCIs have the ability to move as a vapor through the pores of concrete. When they come into contact with embedded metals, they form a protective, molecular layer on the surface of the metal. The blend of amines used in each product is tailored to the expected application, i.e., admixtures are less volatile (much slower to go into vapor phase) because they are mixed in and evenly dispersed through the concrete from the beginning, whereas surface treatments are more volatile to ensure that they can penetrate to the depth of the embedded reinforcement in a timely manner. Loss of inhibitor from air exchange near the surface of the concrete is accounted for in the dosage rate of the inhibitor. The oldest case histories for MCIs are now more than 25 years old.

MCI materials have been thoroughly tested to show corrosion protection and that they do not affect physical properties of the concrete mix. One of these tests is ASTM C1582.[2] There are two aspects of ASTM C1582; one relates to corrosion inhibiting performance (ASTM G109[3]) and the other relates to the physical properties of the concrete containing additives.

Inhibitor Tests

ASTM C1582

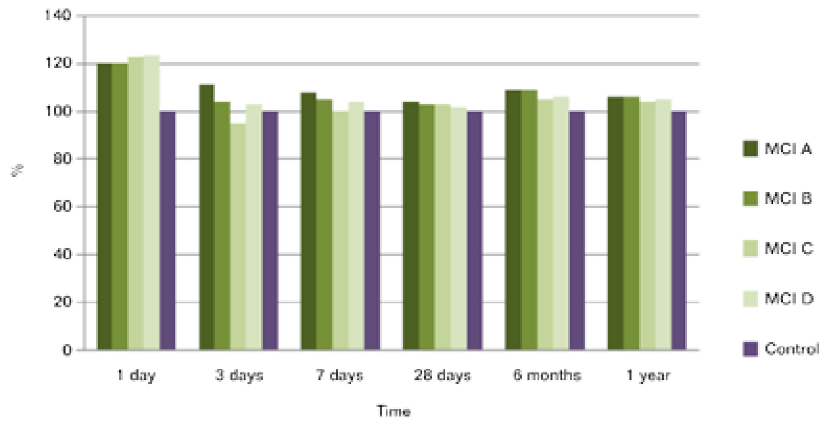
MCI products have little effect on most concrete mix properties. The latest generation of MCI admixtures performs within the acceptable ranges given in ASTM C1582. Figure 1 shows typical results for compressive strength.

ASTM G109

ASTM G109 measures the ability of an admixture to reduce corrosion in concrete exposed to chlorides. Concrete slabs are cast with a triangular array of rebar inside. The top bar is 1.0 in (25 mm) +/− 0.1 in (2.5 mm) from the top of the slab. Salt solution (3.5%) is ponded on the surface for two weeks and then drained. The samples are then allowed to dry for two weeks, so each test cycle is a total of four weeks.

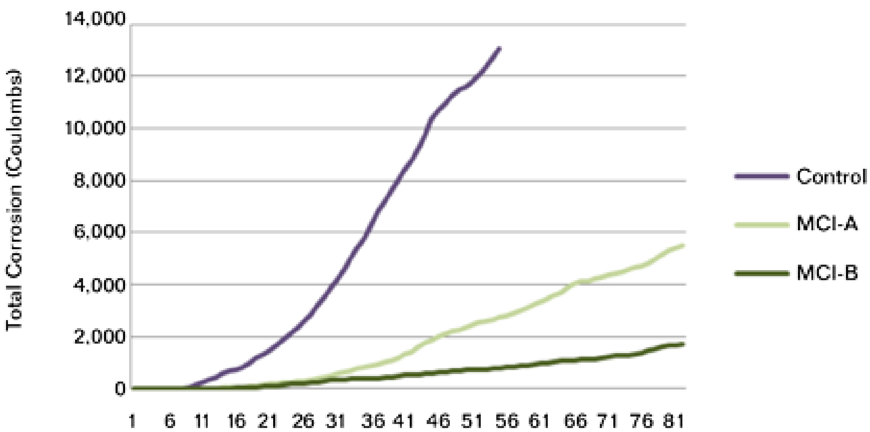
MCI admixtures provide a dual benefit. They extend the time to corrosion

FIGURE 1



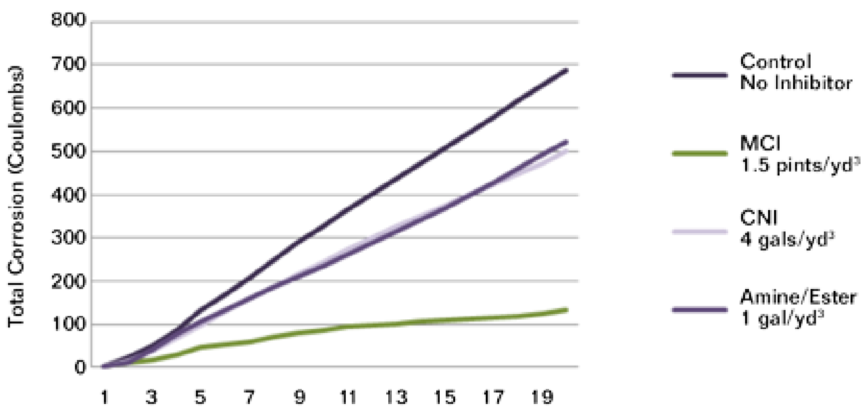
Compressive strength of concrete—MCI compared to control sample.

FIGURE 2



ASTM G109: MCI total compared to control.

FIGURE 3



Cracked beam admixture testing: MCI compared to control, other inhibitors.

initiation compared to a control (double to triple the time to initiation depending on the product), and once corrosion starts, the rates are five to 13 times slower (Figure 2).

Modified G109

A modified G109 test is set up similarly to the standard ASTM G109 test; in this case, however, a small cut is made on the surface of the slab and a load is applied to the ends of the sample to form a crack that goes to the depth of the top bar. This allows the salt solution to reach embedded reinforcement immediately, making the test more aggressive. The test involves one-week cycles (four days wet with a 6% salt solution, three days drying), and a comparison of MCI to two other corrosion inhibiting admixtures. This test highlights MCI's advantages over other corrosion inhibitor products in a situation where a crack forms after construction. The MCI acts on the metal as a protective layer, and its vapor phase ability enables it to replenish itself on the surface of the rebar at the crack, keeping the corrosion rate lower over time. Figure 3 shows that MCI outperforms other admixtures in reducing corrosion in cracked beam structures.

Cracked beam testing was also completed on MCI surface treatment products for existing structures. This test was modified differently from the admixture test. Samples were cast, cured, and cracked. MCI was surface-applied to the top of the slab. Test cycles were one week wet, one week dry for the first month, followed by two weeks wet, two weeks dry for the next 19 months, and a 3% salt solution was used for ponding.

ASTM C157

When designing durable concrete structures that will have a long service life, it is necessary to minimize shrinkage that could lead to cracking. While some corrosion inhibitors are known to increase contraction (shrinkage) of concrete, MCI does not. ASTM C157[4] tests length change (expansion or contraction) of concrete or mortars from various causes other than applied force or temperature change.

MCI-treated mix designs perform similarly to a control (Figure 4). Calcium nitrite (a different type of corrosion inhibitor) increases the amount of shrinkage. Shrinkage can lead to cracking during curing, thus allowing easier ingress of contaminants and can lead to a decreased service life of the structure.

Global MCI Use

Burj Khalifa Building

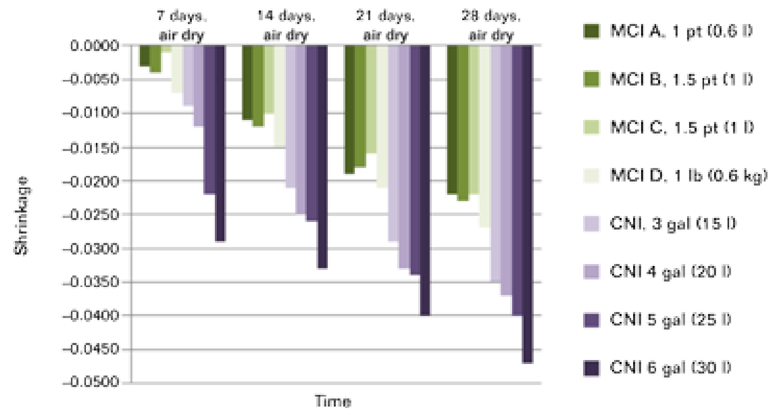
Because MCIs are compatible with most mix designs, as well as with other types of corrosion protection, they have some interesting case histories. The Burj Khalifa, currently the tallest building in the world, is located in Dubai, United Arab Emirates (Figure 5). The structure was designed to have a 100+ year service life, and is exposed to the harsh gulf environment, one of the most corrosive in the world. This means that durability of critical elements (such as foundations, raft slabs, and piles), which are exposed to the environment and cannot be easily repaired, is of utmost importance. To achieve the desired service life, durable concrete containing MCI, and cathodic protection were used in the foundations and piles of the Burj Khalifa as well as many other structures in this region.

Hospital Parking Structure

MCI products also extend the service life of existing structures when used in repair, such as in a hospital parking garage. This structure was built in the late 1980s and was exposed to heavy applications of deicing salts through the years. In 1996, a traffic membrane was applied to the drive surfaces. Moisture in the deck could move out of the concrete only through the bottom of the slab, carrying chlorides with it.

In 2007, an evaluation showed the deck was heavily contaminated with chlorides. Some areas of the deck required full depth replacement (Figure 6[a]). In these areas, ready mix concrete containing an MCI admixture was used. The remaining areas were treated with a surface-applied MCI—both on the drive surface and the underside (Figure 6[b]) to protect both layers of reinforcing steel in

FIGURE 4



Comparison of MCIs with calcium nitrate per ASTM C157.

FIGURE 5

The Burj Khalifa Building in Dubai, U.A.E.

FIGURE 6

(a)

(b)

Hospital parking garage during repair: (a) deck level and (b) underside of deck.

TABLE 1

Location	Average Reading (μA/cm²)
1	2.94
2	3.60
3	0.43
4	0.84
5	1.55

Galvanostatic pulse instrument readings on hospital parking garage taken 2.5 years after application of MCI.

TABLE 2

Corrosion Current, μA/cm^2	Corrosion Rate, μm/year	Corrosion Level	Time to Visible Deterioration
<0.5	<5.8	Passive	N/A
0.5 to 5	5.8 to 58	Low	>10 years
5 to 15	58 to 174	Moderate	3 to 10 years
>15	>174	High	<2 years

Interpretation of corrosion rates of reinforcing steel in hospital concrete parking deck before repair by Thomas Frolund, 2002, using a galvanostatic pulse instrument.

the deck. A 40% silane water repellant was applied to the deck, preventing intrusion of water, but allowing vapor transmission of moisture out of the concrete. Followup corrosion testing showed the repaired deck remains in a state of low corrosion (Table 1). Table 2 shows interpretation of the corrosion rates.

Conclusions

The latest generation of MCI products have been thoroughly tested and used in corrosive applications worldwide. Lab and field test results confirm that MCIs reduce corrosion rates and extend the useful life of concrete and masonry structures, with minimal effect on the concrete properties.

References

1 NSF/ANSI Standard 61, "Drinking Water System Components—Health Effects" (Ann Arbor, MI: NSF).

2 ASTM C1582, "Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete" (West Conshohocken, PA: ASTM).

3 ASTM G109, "Standard Test Method for Determining the Effects of Chemical Admixtures on the Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments" (West Conshohocken, PA: ASTM).

4 ASTM C157, "Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete" (West Conshohocken, PA: ASTM).

JESSI JACKSON MEYER is vice president of Sales–Asia/MCI/Additives at Cortec Corp., 4119 White Bear Pkwy., St. Paul, MN 55110, e-mail: jessij@cortecvci.com. She has B.S. degrees in chemistry and business from the University of Wisconsin, Eau Claire, and has more than 11 years of experience in the construction and corrosion industries. During that time, she has held positions in technical service and sales before becoming vice president of Sales. Meyer holds three patents in the field of corrosion inhibitors used in the concrete/construction market. She has authored several technical papers through NACE International annual conferences and other technical forums. She is an active member of the American Concrete Institute (ACI) and serves on the Board of Directors of the International Concrete Repair Institute (ICRI), both locally and nationally. She also serves on a number of technical committees for ACI and ICRI related to corrosion inhibitors, service life, and sustainability as well as the marketing and chapter committees. MP